Department of Energy

Reducing Aerodynamic Drag for Class 7-8 Trucks

http://energy.llnl.gov/aerodrag

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USC UNIVERSITY OF SOUTHERN CALIFORNIA

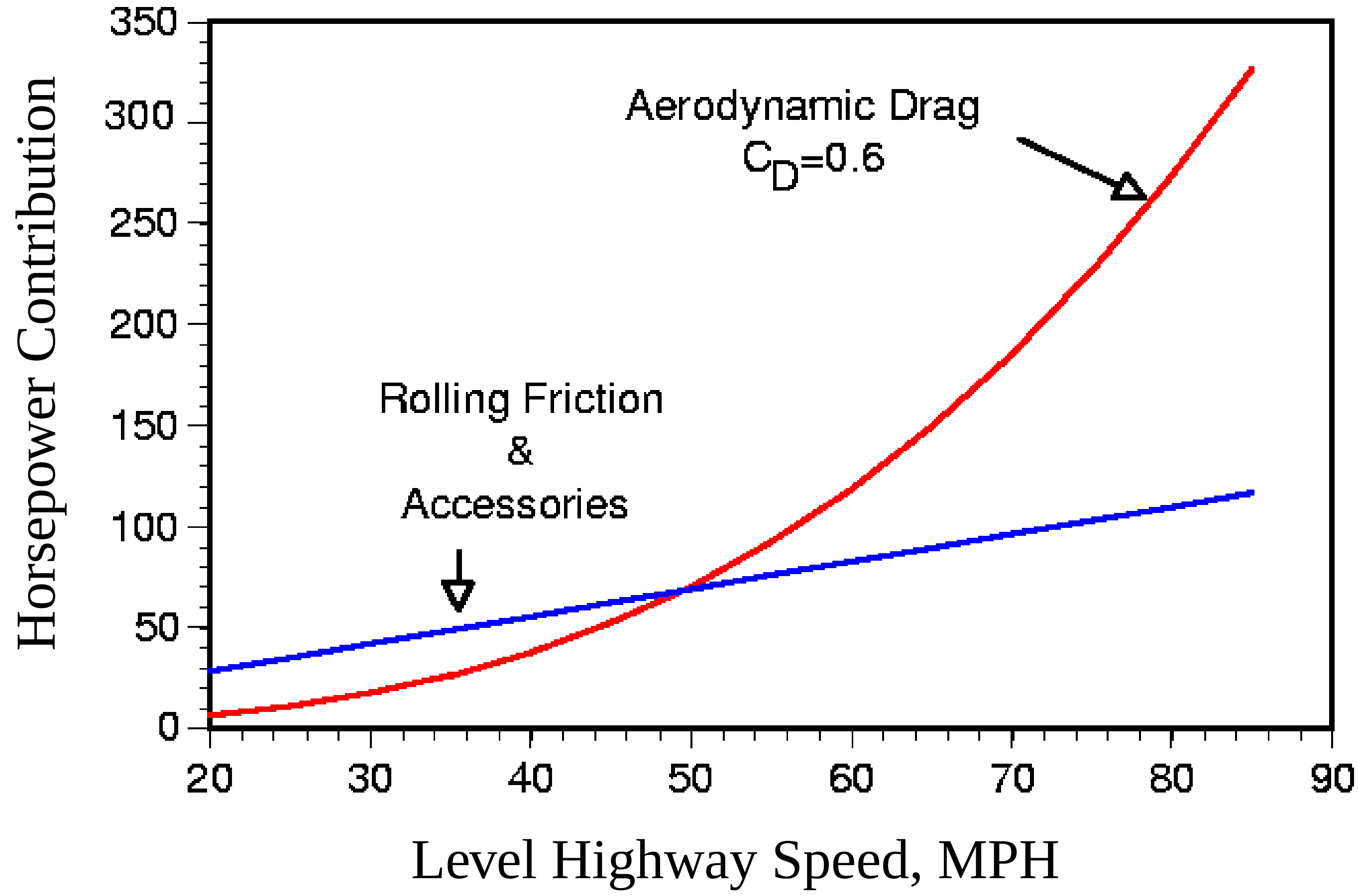
Caltech California Institute of Technology

National Aeronautics & Space Administration

Georgia Tech Research Institute

At 70 mph, 65% of the total energy expenditure is in overcoming aerodynamic drag.

Typical Class 8 tractor-trailer



A workshop in January 1997 was the project kick-off.

DOE Workshop on Heavy Vehicle Aerodynamic Drag, Phoenix, Arizona

Purpose

- Forum for communication
- Determine industry's current practices and technical needs
- Present national lab's and universities' state-of-the-art expertise

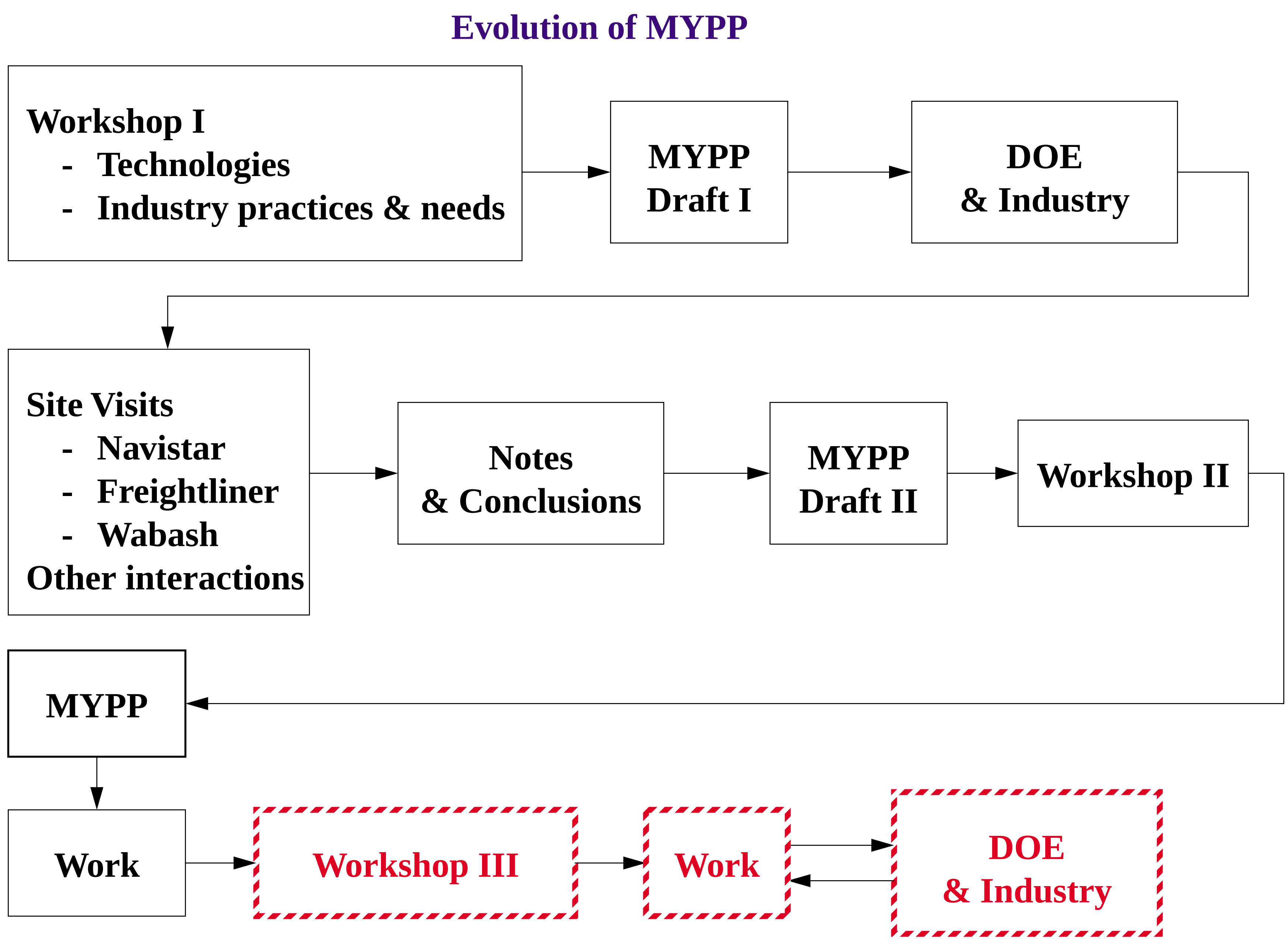
Conclusions

- Trailer design should be the focus of near-term efforts
- An integrated tractor-trailer design is needed
- Advanced computational tools are needed

Action Items

- Form an *Advisory* Committee of industrial participants
- Form a *Technical* Committee to construct MYPP with industry guidance
- Follow-up workshop to finalize MYPP

The Technical Committee's task was to develop a MYPP.



The truck industry relies on wind tunnel and field experiments for aerodynamic design and analysis.

Wind Tunnel Testing

- Costly detailed models
- Expensive tunnel use
- Trial-error approach to determine drag effects

Cabover Engine

Field Testing

- Performed by both manufacturer and fleet operators

Conventional

Issues

- A tractor is paired with several different trailers
- Almost no aero design interaction between tractor and trailer manufacturers

The effects of design changes on drag are not well understood and computational guidance is needed

The project focus is based on industry needs and consideration of current technology, funding, and DOE interests.

DOE and National Laboratory interest

- Reduce heavy vehicle drag -> reduce fuel consumption and emissions
- R&D for DOE programs

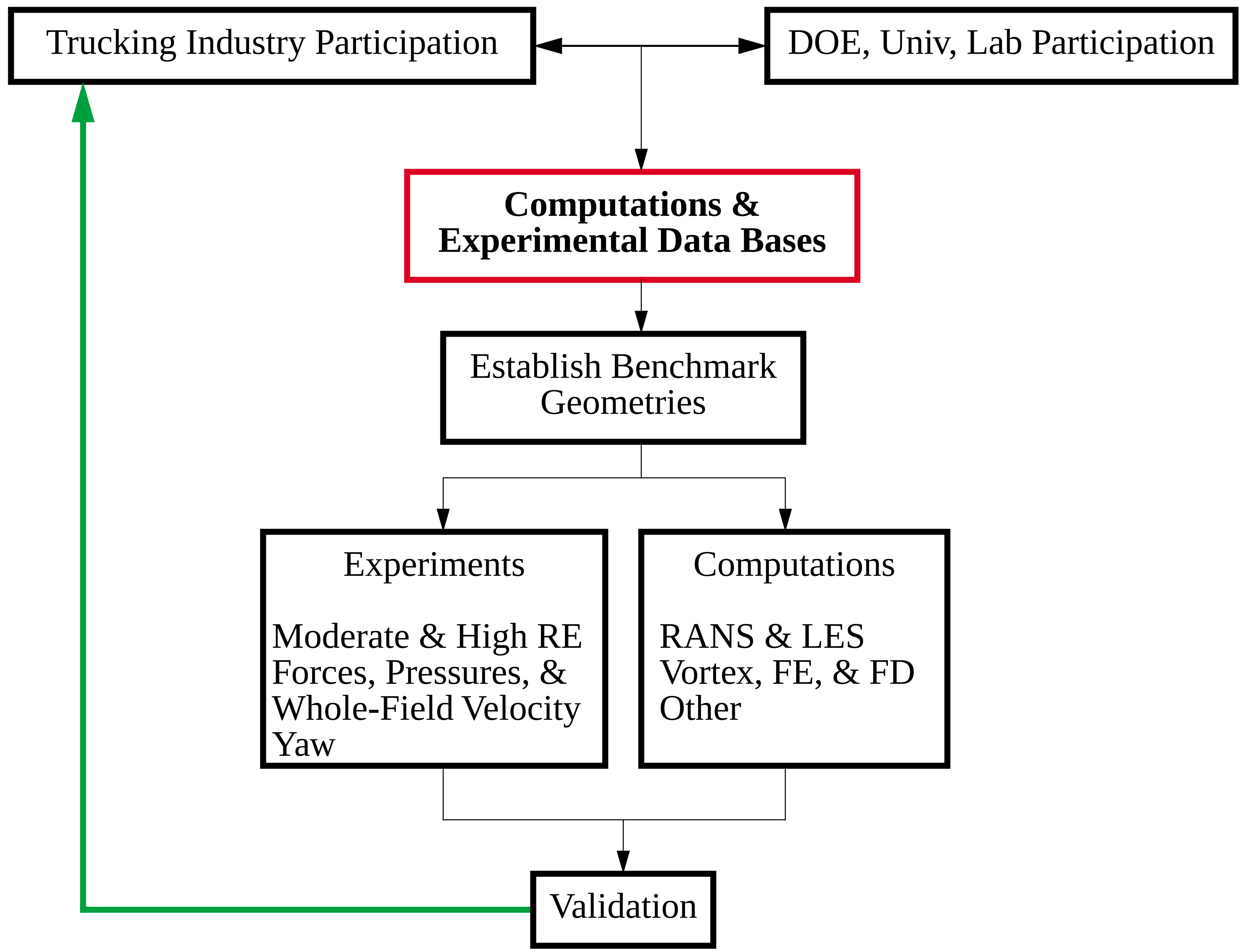
Industry needs

- Advanced validated computational tools and experimental techniques
  - Understand the effects of design changes
  - Simulate fully-integrated tractor-trailers
- Design improvements for drag reduction

Current technology - CFD is hard!

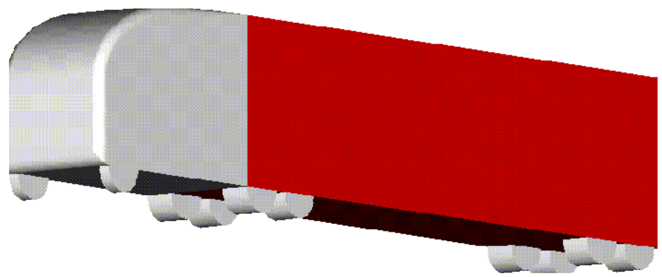
- Direct numerical simulation (DNS) - required resolution makes problem too big
- Reynolds-averaged Navier Stokes (RANS) is common approach
- Large-eddy simulation (LES) is in development
- Detached-eddy simulation (DES) is in development

The project focus is on development and demonstration of a simulation capability.



Near-term goal is to compare RANS and LES with experimental data for a truck problem.

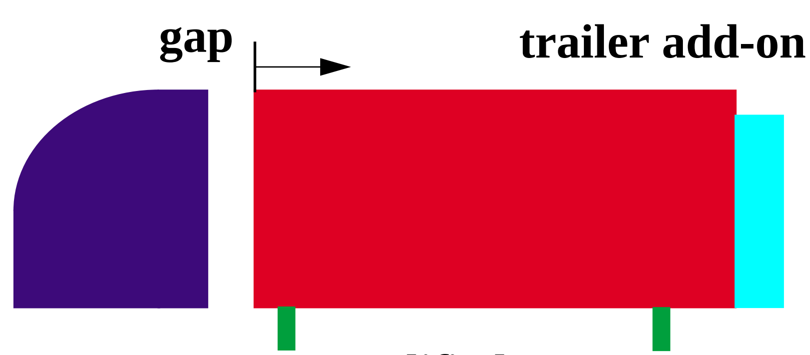
Ground Transportation System (GTS)



Advantages

- **Simple geometry**
- **Some existing data**
- **Some modeling already done**

baseline GTS



modified GTS

Each organization’s contributions are critical to the project’s success.

Experimental Modeling

Walt Rutledge

Sandia National Laboratories

GTS Experiments at Texas A&M

Fred Browand
Mustapha Hammache

USC UNIVERSITY OF SOUTHERN CALIFORNIA

Moderate Speed Experiments in Wind Tunnel

Jim Ross
Bruce Storms, JT Heineck

National Aeronautics & Space Administration

High Speed Experiments in 7’x10’ Wind Tunnel

Computational Modeling

Rose McCallen (PI)

University of California Lawrence Livermore National Laboratory

Large-Eddy Simulation using Finite Element Methods

Anthony Leonard
Mark Brady

Caltech California Institute of Technology

Large-Eddy Simulation using Vortex Methods

Kambiz Salari
Walt Rutledge

Sandia National Laboratories

Reynolds-Averaged and Detached-Eddy Simulations using Finite Volume Methods

Bob Englar

Georgia Tech Research Institute

Active Systems

Heavy vehicle simulations require turbulent flow approximations.

DNS : Direct numerical simulation

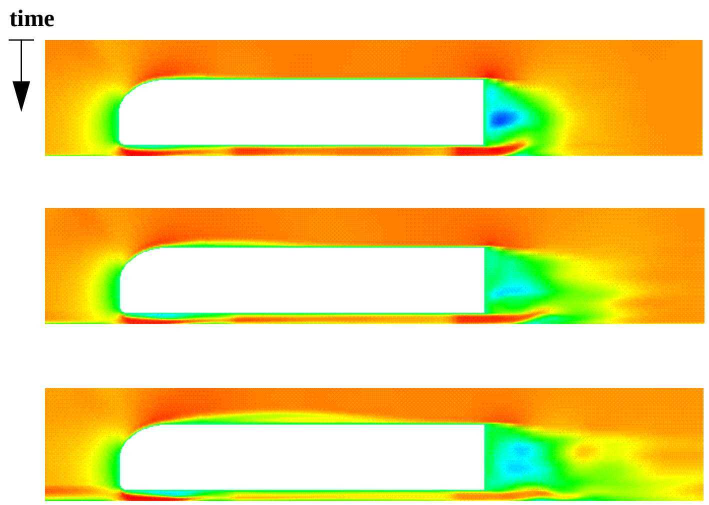
Resolution of smallest eddies - problem too big for computer

Being used for code validation with small problems

RANS : Reynolds Averaged Navier-Stokes

Average ‘steady’ solution

Widely used - may not predict drag correctly



streamwise velocity contours

LES : Large-eddy simulation

Unsteady solution of large scales

Approximation of small scales - less empiricism

Relatively new - computationally more intensive

DES : Detached-eddy simulations

RANS near truck surface / LES away from truck surface

Very new

Compressible as well as incompressible simulations are being performed.

Experiments

Compressible (Ma > 0.1)

NASA 7'x10'	**Re = 2,000,000**	**Ma = 0.27**
Texas A&M	**Re = 1,600,000**	**Ma ~ 0.2**

Incompressible (Ma < 0.1)

NASA 7'x10'	**Re ~ 740,700**	**Ma = 0.1**
USC	**200,000 < Re < 400,000**	

The benefits of various numerical approaches are being investigated.

FVM : Finite volume method

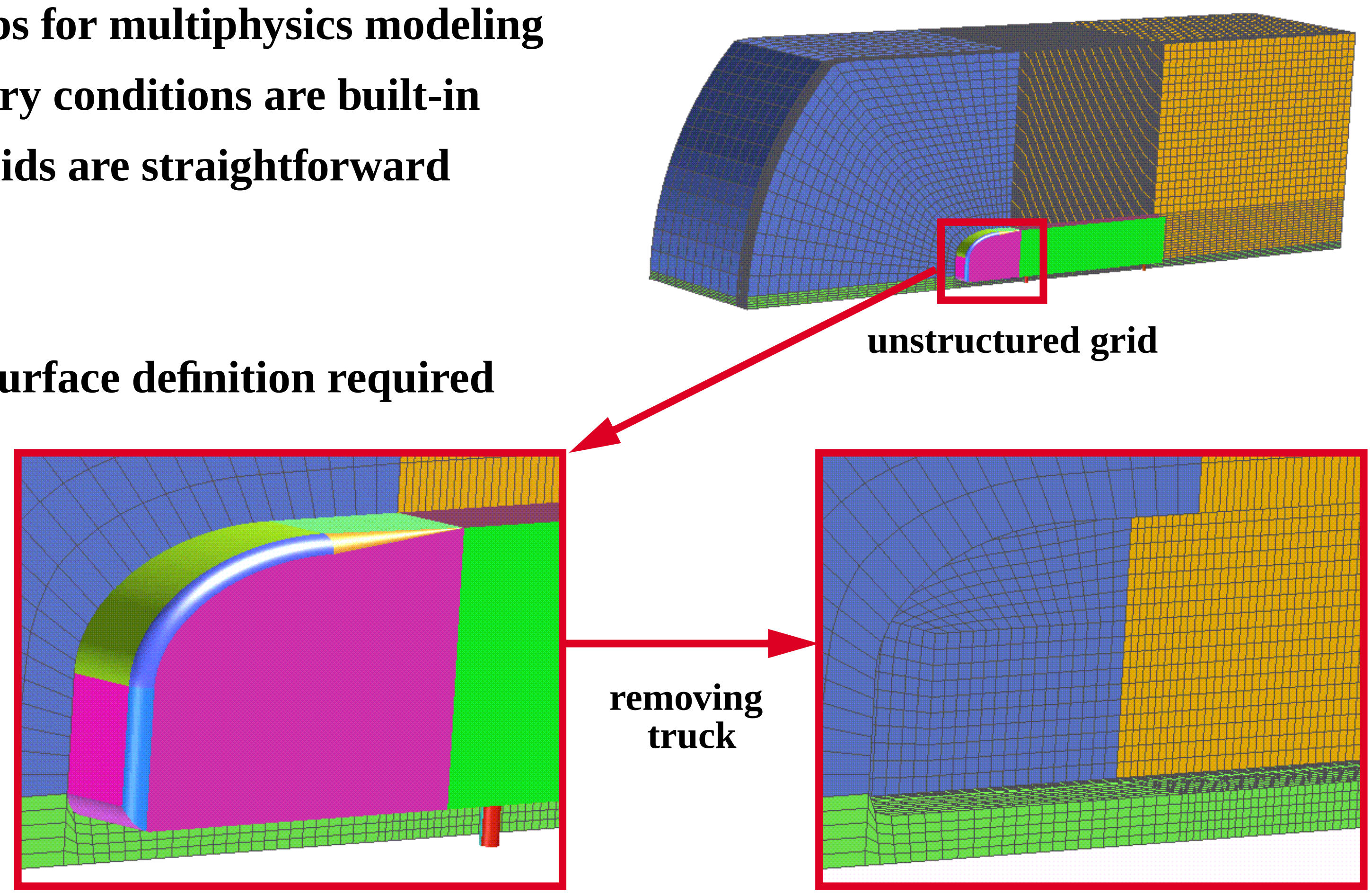
- Widely used

FEM : Finite element method

- Widely used for solid mechanics
- Used at DOE labs for multiphysics modeling
- Outflow boundary conditions are built-in
- Unstructured grids are straightforward

Vortex method

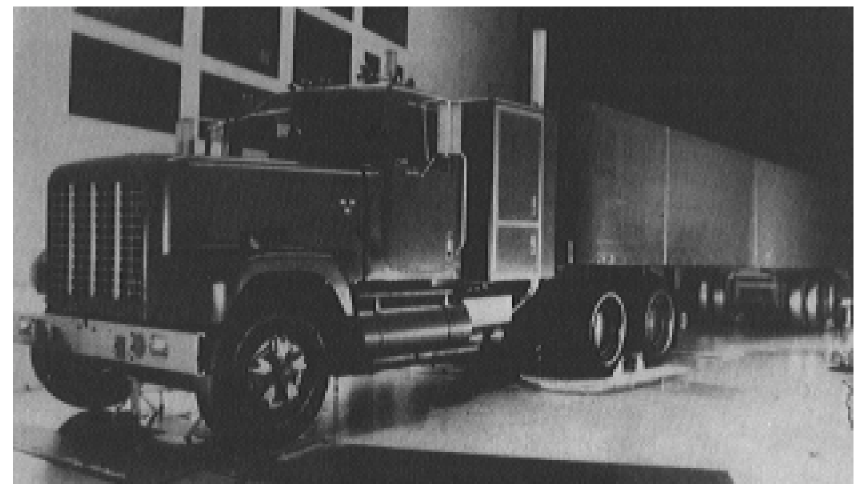
- In development
- Gridless - only surface definition required



The DOE is interested in improved heavy vehicle thermal management for fuel reduction.

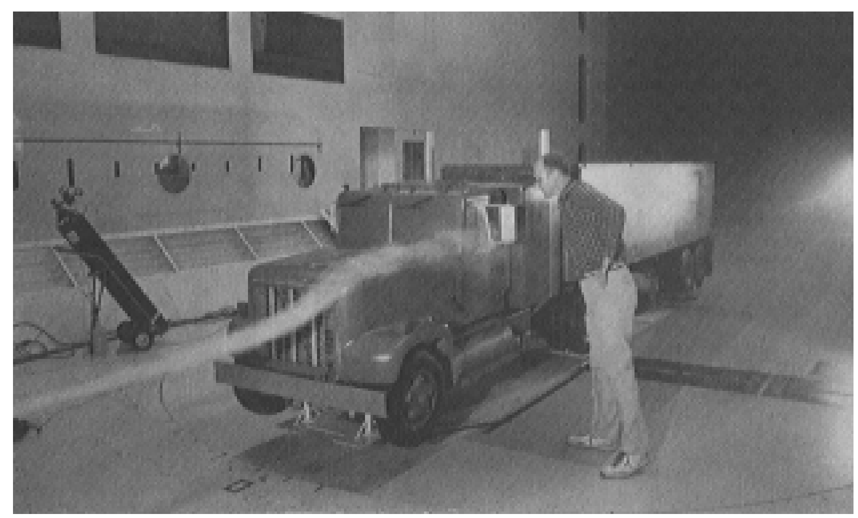
The engine cooling airflow contributes to aerodynamic drag

1970's - 1980's Designs



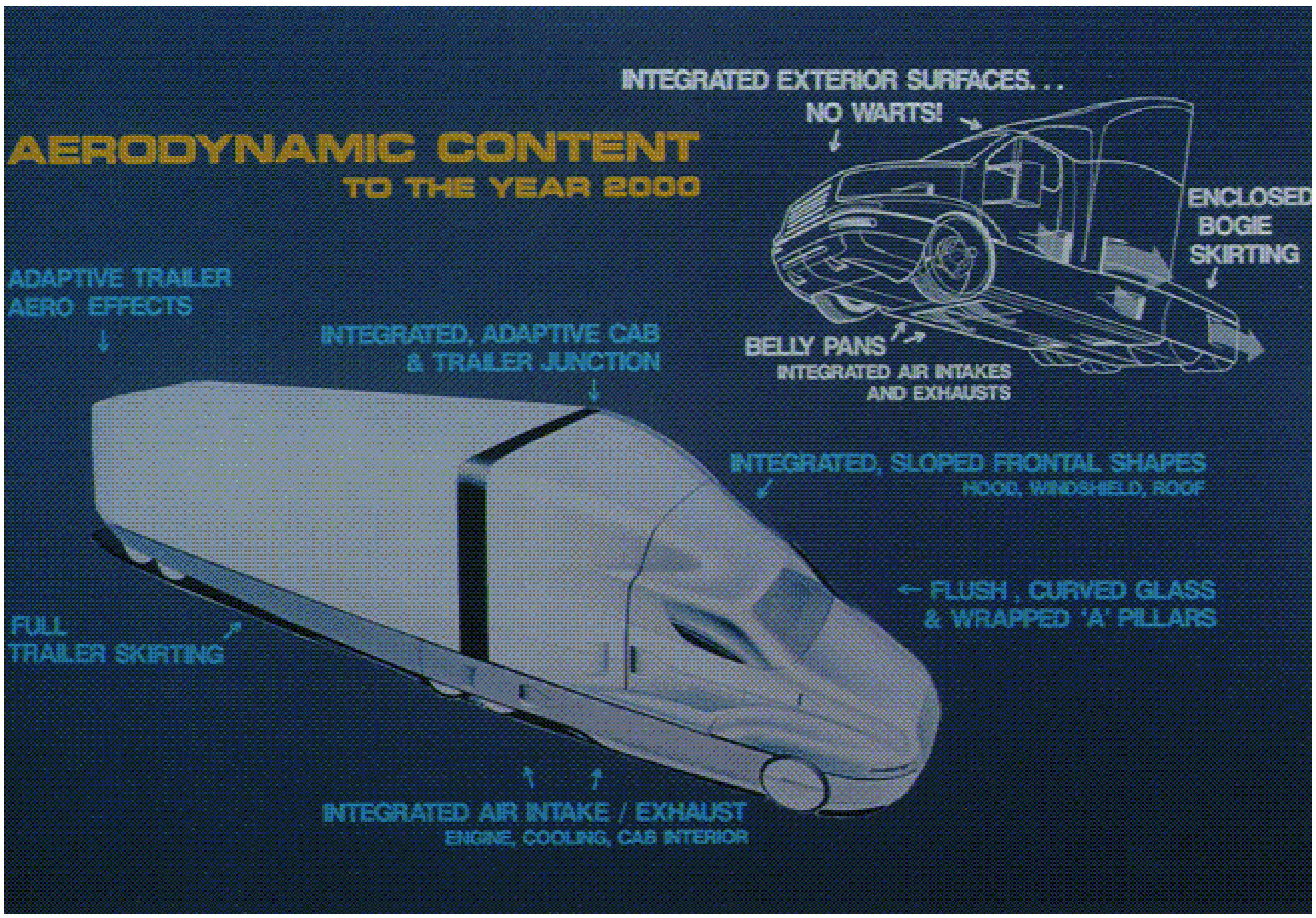
$\overline{C}_{Dtotal}$ = 1.0 - 0.85

engine air cooling is 3.8% of $\overline{C}_{Dtotal}$



Ref. Olson and Schaub, 1992, SAE 920345

The designs of tomorrow will be integrated and emphasize internal and external flow management.



Navistar International Transportation Corp.